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DESIGN OF MECHATRONICS ENGINEERING ASSOCIATE DEGREE PROGRAMS – AN OVERVIEW

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ABSTRACT

After reviewing Mechatronics programs from numerous international educational organizations, this proposed course outline and unit descriptions have been prepared for associate degree programs in Mechatronics engineering. Over the period of more than two months, we have carefully analyzed and reviewed relevant program details including required courses and their outlines, pre and co-requisites, labs work requirements and other relevant details. A time-frame of 8 to 10 months is required for starting the first batch of Mechatronics Associate degree in colleges where Mechanical and Electrical/ Instrumentation programs are already being offered. It is because this program employs a multi-disciplinary approach and necessitates a synthesis of disciplines. However, this recommended time to commence the course offering after necessary design and development steps can vary significantly depending on the status of existing courses and their alignment with objectives associated with Mechatronics courses. Recommendations produced in this paper include relevant objectives from the programs and proposed units in alignment with ABET Engineering Accreditation Commission's criteria for the year 2016-17.

INTRODUCTION

In the rapidly changing economic scenarios in the modern world, Industrialization remains the strategic choice in accelerating the achievement of economic development objectives (Kniivilä, 2007). Advances in industrialization, in turn, are heavily dependent on technological progress. Technology dimensions are expanding at a very rapid pace (Basalla, 1988; Geels, 2005; Jenkins & Floyd, 2001; Nelson, 1994). This poses a major challenge to technology education institution to keep their students well versed with the modern industrial processes and technology innovations (Holbrook, 2009; Sjøberg, 2002; West, 1999). Industries are moving towards flexible mechanisms for the improvement in design, production, planning and engineering design. This has started an era of 'cross-functional thinking' (Davenport, Short, & others, 1990; Holland, Gaston, & Gomes, 2000; McDonough, 2000) and 'collaborative approach' (Bychkovskiy, Megerian, Estrin, & Potkonjak, 2003; Highsmith, 2013; Jones, Rasmussen, & Moffitt, 1997; Mishne, 2006) for industrial problem solving. This requires various engineering disciplines to come together and work collaboratively to meet the future challenges.

Mechatronics is a discipline that can bridge the existing divide between electrical/instrumentation and mechanical engineers fostering an innovative culture and yielding more cross-functional productivity improvements initiatives. Mechatronics is a synergistic approach aiming at the integration of mechanics, electronics, control theory, and computer science within product design and manufacturing, in order to improve and optimize industrial applications and processes (Kyura & Oho, 1996). In a didactic approach to mechatronics, the academic subject can be defined according to four dimensions: identity, legitimacy,

selection and communication. A result of defining the legitimacy of mechatronics as functional is that the ultimate identity can be viewed as thematic (Grimheden & Hanson, 2005).

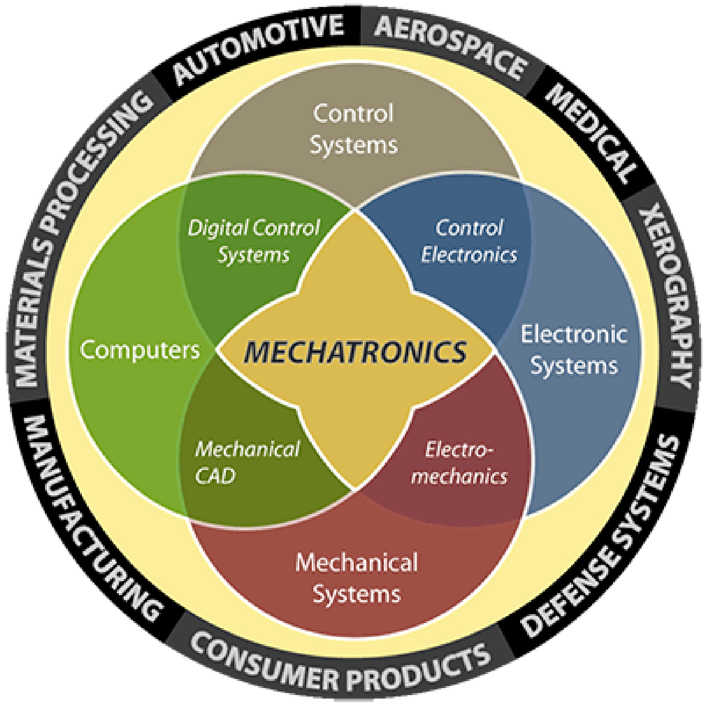

Figure 1 Mechatronics as a synergistic approach

Mechatronics is a multidisciplinary approach and requires integration between different engineering and technology branches in order to produce intelligent systems. Some common industrial examples of Mechatronics systems include:

- Automation (PLCs, Microcontrollers etc)
- Machine Vision Systems
- Manufacturing of electronics equipment
- Robotics Design and Operation
- CNCs Machining Systems
- SCADA Systems
- Machinery Diagnostics
- Consumer Products Industry
- Product and Process Quality Assurance

High levels of automation in manufacturing and service environments require a multi-disciplinary approach. Systems have sophisticated mechanical designs and require automation system designer to have a background in mechanical sciences as well. Most of the projects and service tasks fail because of lack of knowledge or coordination in the working team. Mechatronics engineering is meant to bridge this industrial skill gap. Graduates from this program are expected to add great value to industries they work for because of their diversified engineering knowledge and hands-on training.

Many industrial colleges offer effective technology programs in the disciplines of Mechanical, Electrical and Computer Engineering which cover different aspects of Mechatronics technology program. The curriculum for Mechatronics programs is designed in a way to SYNERGISE these skills, keeping in mind the industrial requirements.

While proposing the framework for this associate degree program, we have considered relevant requirements from ABET. ABET, incorporated as the Accreditation Board for Engineering and Technology, Inc., is a non-governmental organization that accredits post-secondary education programs in "applied science, computing, engineering, and engineering technology" (“About Abet | ABET,” 2016). ABET currently accredits 3,569 programs at 714 colleges and universities in 29 countries. It is to be noted that the current list of engineering technology or associate degree programs that can be recognized by ABET does not include Mechatronics. However, it can be offered under other relevant titles such as Electro-mechanical engineering technology or instrumentation and control systems engineering. Adjustment in units may be required to accommodate needs to these specific programs.

In this proposed program framework, we have covered relevant details from the accreditation criteria with regards to course objectives, student outcomes, and curriculum design. However, there are other aspects as well which need compliance before the accreditation is achieved. Institutions planning to comply for accreditation will need to go through all relevant requirements and ensure compliance. Another important aspect to consider in this regard is the changes in accreditation criteria over the years. The current proposal is based on criteria for the year 2016-17. In subsequent years, latest version at that time should be followed.

PROGRAM OBJECTIVES AND OUTCOMES

Based on our research, we propose following objectives for the program.

In line with ABET accreditation requirements, programs are required to have well-defined objectives. According to ABET, “Program educational objectives are broad statements that describe what graduates are expected to attain within a few years after graduation. Program educational objectives are based on the needs of the program’s constituencies” (“Criteria for Accrediting Engineering Technology Programs, 2016 – 2017 | ABET,” 2016). ABET’s accreditation criteria in this regard stipulate that “the program must have published program educational objectives that are consistent with the mission of the institution, the needs of the program’s various constituencies, and these criteria. There must be a documented, systematically utilized, and effective process, involving program constituencies, for the periodic review of these program educational objectives that ensures they remain consistent with the institutional mission, the program’s constituents’ needs, and these criteria” (“Criteria for Accrediting Engineering Technology Programs, 2016 – 2017 | ABET,” 2016).

Objective of Mechatronics Technology Associate program is to enable its graduates to:

- Assume entry level position in industries to deliver services and support to internal and external clients by applying technical knowledge, problem solving and hands-on skills, in traditional and emerging areas of Mechatronics and related disciplines.

- Adapt to changes in technology and proactively apply current knowledge and problem-solving skills in order to support mechatronics and other relevant system components.

- Perform professional activities with integrity, a sense of social, ethical and environmental responsibility, attention to safety and occupational health, teamwork, and effective communication.

- Demonstrate success in the chosen careers through promotion, occupational mobility, and demonstration of leadership skills in their organizations and professions.

- Achieve professional excellence and knowledge advancement through higher education, on-job training, and relevant certifications.

Following Outcomes are expected from Mechatronics Technology Program. According to ABET, "Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program" ("Criteria for Accrediting Engineering Technology Programs, 2016 – 2017 | ABET," 2016). ABET's criteria in this regard state that the program must have documented student outcomes that prepare graduates to attain the program educational objectives. There must be a documented and effective process for the periodic review and revision of these student outcomes.

ABET requires following outcomes from the programs:

a) an ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities;
b) an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge;
c) an ability to conduct standard tests and measurements, and to conduct, analyze, and interpret experiments;
d) an ability to function effectively as a member of a technical team;
e) an ability to identify, analyze, and solve narrowly defined engineering technology problems;
f) an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
g) an understanding of the need for and an ability to engage in self-directed continuing professional development;
h) an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity; and
i) a commitment to quality, timeliness, and continuous improvement.

In accordance with above, following is a set of proposed student outcomes from associate engineering degree level courses in mechatronics. Students from Mechatronics courses at associated degree level should be able to:

- Apply the principles of mathematics and applied science to perform technical calculations and solve technical problems of the types commonly encountered in mechatronics engineering technology. (Consistent with ABET criterion 3, points a-e)
- Be able to perform competently in a laboratory setting, taking measurements, operating technical equipment, critically examining and reporting experimental results, and indicating the potential for process improvements. (Consistent with ABET criterion 3, points a-e, i)

- Be able to use modern computational tools for technical problem solving including scientific calculators, relevant lab equipment, computers and technical software. (Consistent with ABET criterion 3, points a, c)

- Be able to demonstrate broad basic education and knowledge of contemporary issues in global and societal contexts as required to develop professional and ethical responsibility to employers and society at large. (Consistent with ABET criterion 3, points a, b, d, g, f)

- Be able to recognize the need for life-long learning and continuous professional development in the field of mechatronics engineering technology. (Consistent with ABET criterion 3, points g, h)

- Be able to demonstrate the ability to communicate and function effectively with members of multi-disciplinary teams and other members and workers from various backgrounds in an industrial setup. (Consistent with ABET criterion 3, points d, f)

- Be able to demonstrate a commitment to quality, punctuality, and continuous improvement. (Consistent with ABET criterion 3, point I, criterion 4)

- Be able to demonstrate proficiency in technical knowledge and skills, effective communication, and strength of character in order to take up supervisory and other leadership roles in the industry. (Consistent with ABET criterion 3, points f, g, h)

STUDY PLAN - CURRICULUM DESIGN APPROACH:

Study Plan for Mechatronics Engineering Technology Program is developed through the following:

- Detailed review of courses from renowned universities worldwide
- Specific and relevant industrial skills needs for the kingdom addressed
- Gradual student skill development process followed
- PROJECT/ practical based approach (one project per semester) in order to equip Mechatronics students with hands-on knowledge and problem-solving abilities
- Laboratory activities are an integral part of the program and include tutorials, case studies, group discussions, role model exercises, video exhibits and visits to renowned industrial establishments.

Units:

Units are structured as per figure 2.

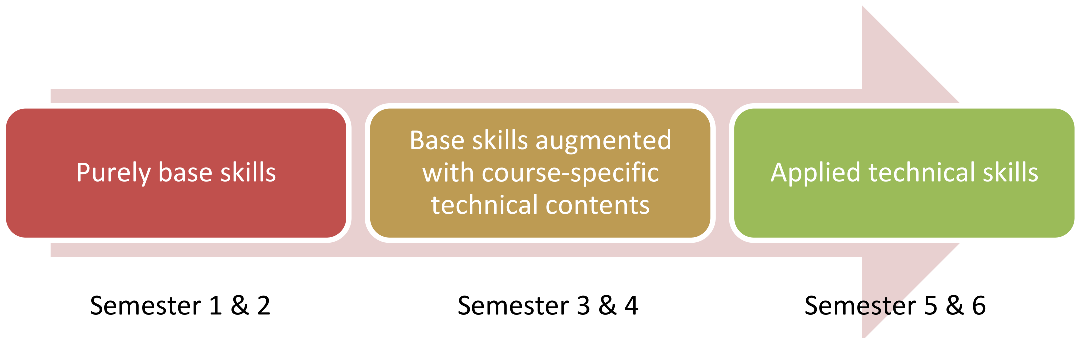

Figure 2 Associate Degree Progressions

It is to be noted that ABET criterion 5, TECHNICAL CONTENT – point a states that key technical content has to be more than 1/3 of the total program but should not be more than 2/3. Our proposed structure adheres to this requirement as explained in figure 2.

ABET criterion 5, TECHNICAL CONTENT – point b requires that program should "include a technical core that prepares students for the increasingly complex technical specialties they will experience later in the curriculum." We have ensured a gradual progression of learning and cohesion by exposing students to core skills required for more advanced courses they are going to work with in later semesters.

Our courses, complemented with labs, with also satisfy ABET criterion 5, TECHNICAL CONTENT – point c which requires the development of student competency in the use of equipment and tools common to the discipline.

Semester 1 and 2:

In semester 1 and 2, we propose units that help students in gaining core study skills including 'proficiency in English language', 'introduction to technology (basic engineering skills including workshop operations, welding, machining etc.), mathematics (algebra and trigonometry), physical education, drafting and introduction to computing for mechatronics applications.

It is to be noted that ABET accreditation criteria 5, which specifies details about the curriculum for associate degrees requires mathematics education to include algebra and trigonometry. Proposed course selection will address ABET Criterion 5, MATHEMATICS - point a.

Semester 3 and 4:

In semester 3, English language skills can be developed further with a focus on communication and composition. Mathematics skills should focus on calculus to prepare students for subjects coming in later semesters. Physics can be included to assist students with electronics related subjects. In this

semester, students can also be exposed to electronics circuit fundamentals. Graphics skills can be progressed further with the inclusion of drafting techniques for mechatronics design.

In semester 4, chemistry can be included. It can be swapped with physics in semester 1/2 if required. Mathematics skills can be advanced by adding units on calculus. It is to be noted that it is in accordance with ABET Criterion 5 in terms of including physical/ natural sciences in the curriculum.

From mechatronics units, semester 4 seems to be the suitable option for inclusion of units on 'Applied Mechanics' and 'Mechatronics measurements'. Electronic circuit fundamentals introduced in previous semesters can be progressed further by the inclusion of a unit on 'Introduction to electronics'.

Semester 5:

By this time, students would have acquired basic mechanical and electronics skills in addition to key engineering study skills. In semester 5 and 6, this knowledge can be applied to acquire deeper and more applied skills in the discipline.

In semester 5, we recommend inclusion of subjects on 'Maintenance and troubleshooting', 'Mechatronics fundamentals', 'Mechatronics systems', 'Digital electronics' and 'engineering programming'.

As we go more into applied aspects of the discipline, a course on industrial safety can be very suitable for this semester. Also, mathematics skills for more advanced calculations can be progressed with a unit on 'applied differential equations'.

Semester 6:

Semester 6 continues with applied skills.

Based on programming skills acquired in semester 5 and combining it with the knowledge of digital electronics, students can now study 'Microcontrollers and Microprocessor applications'.

Students can also be given the opportunity to advance their skills in 'Industrial Electronics', 'Control Systems' and 'Mechatronics systems' by the inclusion of relevant units on these subjects. Mechatronics systems can act as an umbrella unit which can include a number of relevant areas based on specific priorities of local industries and engineering education provider.

At this stage, we also recommend inclusion of a unit on research methods which should also require students to write a research report.

All students will be required to complete co-operative attachment/ internship at the end of course to gain practical experience. This is also in accordance with ABET criterion 5 in relation to 'cooperative education'.

CONCLUSION AND RECOMMENDATIONS:

In this paper, we have proposed a course framework for Mechatronics engineering associate degree program in line with ABET's criteria for the year 2016-17. This can be a good starting point for organizations planning to launch relevant programs. This is a baseline proposal and further customization and contextualization will be essential before the implementation and course design. Mechatronics is an important skill for current and future industry and effectively designed educational interventions can be very valuable in ensuring high productivity and growth of industrial operations through the deployment of appropriately trained mechatronics graduates and technologists.

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